

**NASA Astrobiology Early Career Collaboration Award Report:
The Nature and Genesis of Organic Matter in Pristine Meteorites**

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Trip 1: Monday 10th – Saturday 15th November 2014

Trip 2: To be scheduled.

Location: Beamline 5.3.2.2, Lawrence Berkeley National Laboratory's (LBNL) Advanced Light Source (ALS) Synchrotron, Berkeley, California.

Purpose: I collaborated with **Dr. David Kilcoyne** to perform spectral analyses of extraterrestrial organic matter (OM) at LBNL's ALS Synchrotron. I am using a coordinated microanalytical approach to investigate the effects of aqueous alteration on OM in a single sample (Antarctic chondrite MIL 07687) at the sub-mm scale to determine how OM evolves on asteroids. Critical to this study is the use of X-ray absorption near edge structure (XANES) spectroscopy, sometimes also known as Near-Edge X-ray Absorption Fine Structure (NEXAFS), at the ALS synchrotron. XANES is a type of absorption spectroscopy that can identify the approximate nature of organic species in a sample by determining the type of bonds present, which are associated with characteristic spectral energies. The XANES analyses were performed using the scanning transmission X-ray microscope (STXM) on beamline 5.3.2.2 (Kilcoyne et al. 2003).

Outcome: To date, I have extracted and analyzed two fragments of OM identified in situ in the carbonaceous chondrite MIL 07687. Both samples have been analyzed at the ALS via XANES spectroscopy and subsequently via Transmission Electron Microscopy (TEM) at the Naval Research Laboratory (NRL) in Washington, DC. On the most recent trip to the synchrotron (November 2014) I also performed XANES spectroscopy on OM that was extracted from crushed bulk meteorite (IOM: Insoluble Organic Matter) to determine how representative the in situ OM was.

Preliminary results show that OM from two regions of the sample, which have experienced variable degrees of asteroidal alteration, shows similar functional chemistry (mixed aliphatic and aromatic components) (Fig. 1). More significant differences are seen in the general mineralogy of the two different regions. The more altered matrix contains widespread OM, which is typically associated with cracks, voids, and carbonates (secondary minerals associated with aqueous alteration), suggesting that OM has been redistributed by fluid action on the parent asteroid. Some heterogeneity is seen in the nature of the OM in the more altered region of matrix (i.e., more pronounced carboxyl peak as a result of oxidation of OM via water). However, the OM is not as 'evolved' as seen in more altered meteorites such as the CM2 Murchison and CI1 Orgueil (Le Guillou et al., 2014), suggesting it experienced low-grade alteration. This is consistent with the mineralogy of the sample.

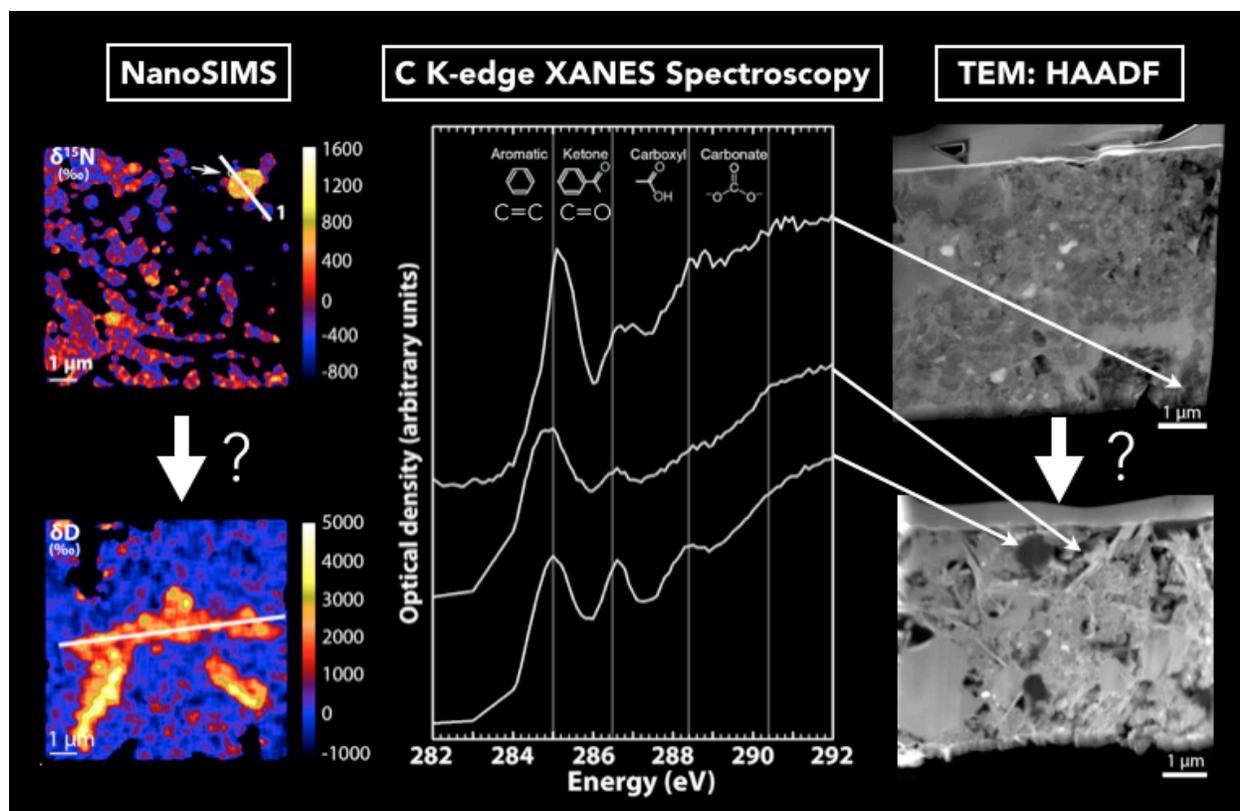


Figure 1. Correlated NanoSIMS isotopic composition maps, C K-edge XANES spectra, and TEM HAADF images showing the differences in organic matter in variably altered regions of the MIL 07687 Antarctic chondrite. Arrows indicate progression of alteration.

Future plans: More sections containing OM will be removed from a number of different regions of the matrix to ensure that a whole range of different aqueous alteration environments are analyzed.

Presentation and Publication of Results: I gave oral presentations at the Fifth Symposium on Polar Science in Tokyo, Japan in December, 2014 (Davidson *et al.*, 2014) and the 46th Lunar and Planetary Science Conference in Houston, Texas on March 19th (Davidson *et al.*, 2015; see attached abstract) to present the preliminary findings of this study. The final data will be submitted to either *Earth and Planetary Science Letters* or *Geochimica et Cosmochimica Acta* for peer-reviewed publication later this year.

References:

- Davidson J., Nittler L. R., Stroud R. M., Takigawa A., Alexander C. M. O'D., Kilcoyne A. L. D., and Cody G. D. **2014**. Carbonaceous material in the unique carbonaceous chondrite Miller Range 07687: A coordinated NanoSIMS, FIB-TEM, and XANES study. *37th Symposium on Antarctic Meteorites*. Tokyo, Japan.
- Davidson J., Nittler L. R., Stroud R. M., Takigawa A., De Gregorio B. T., Alexander C. M. O'D., Kilcoyne A. L. D., and Cody G. D. **2015**. Organic matter in the unique carbonaceous chondrite Miller Range 07687: A coordinated in situ NanoSIMS, FIB-TEM, and XANES study. *46th Lunar and Planetary Science Conference*. Houston, Texas.

- Kilcoyne A. L. D., Tyliszczak T., Steele W. F., Fakra S., Hitchcock P., Franck K., Anderson E., Harteneck B., Rightor E. G., Mitchell G. E., Hitchcock A. P., Yang L., Warwick T., and Ade H. **2003**. Interferometer-controlled scanning transmission X-ray microscopes at the Advanced Light Source. *Journal of Synchrotron Radiation* **10**, 125–136.
- Le Guillou C., Bernard S., Brearley A. J., and Remusat L. **2014**. Evolution of organic matter in Orgueil, Murchison, and Renazzo during parent body aqueous alteration: in-situ investigations. *Geochimica et Cosmochimica Acta* **131**, 368–392.